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EVALUATION OF CAR ACCIDENT PARAMETERS DURING COLLISION

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Abstract. According to he literature source [5], almost 47-52 % from all carcrashes make collisions of cars. So it is possible to conclude that almost each second a carcrash is a collision.

One of the most important parameters that should be determined during carcrash investigation is the car speed before the accident. Calculation of the parameters in various situations differs. The experts performing the investigation work of car crashes improve or create carcrash investigation methods in various cases.

The methods of speed determination before crashes are presented in these cases: direct collision, when cars move one after another, direct sided collision and sided sliding collision as well.

Keywords: accident, collision, speed.

1. Introduction

According to statistical data it is possible to conclude that each year 0,5 million of people are killed and almost 20 million are injured in car accidents. Each year mankind suffers tremendous material damage because of the accidents. Fox example these losses in Lithuania made 1,7 milliard of litas (According to "Loss of carcrashes evaluation methodics") in 2001 [1].

An accident always gives losses – both – economic and social; most people and enterprises suffer from the violation of their rights and interests. So the question of investigation of car accidents becomes very important. The investigation of car accidents requires much thorough work and it is very complicated. Usually accidents take place in a moment, per several seconds and even their parts. This factor complicates the process of investigation.

As the sources of literature [2] indicate the main purpose of the investigation is not only to determine the culprit, but also to analyse the reasons and the factors of the traffic accident. The information is used in the programs of prevention.

In the process of the investigation the main purpose of an expert is to restore the sequence of an action from the beginning of the emergency situation up to the moment of the accident itself, to determine the reason and a culprit as well. Accurate determination of the event mechanizm often reveals the real reason of the acecident. It is very difficult work. Because of rapid development of software most companies in the West create special programs helping to restore the sequence of the accident German and other West Countries work hard in the field. Companies in the USA have made progress here. One of them is EDC (Engineering Dynamics Corporation), founded in Oregon state (USA). The products of the company are software packets for the investigation of accidents. For example EDCRASH (Engineering Dynamics Corporation Reconstruction of Accident Speeds on the Highway). The program serves for the investigation of car accidents in country side territories or highways. The program models the sequence of the accident according to the initial data. The program works with one or two accident situations. The program allows to determine the position of the crash and the trajectories of movement.

Another product - EDSMAC (Engineering Dynamics Simulation Model of Automobile Collisions) serves for the investigation of car collision. The company presents other programs for the investigation of various traffic situations.

As the authors of the article are informed, there are not any legal programs serving the above mentioned purposes in Lithuania. There are not any unified methodics for the investigation of car accidents as well.

The accident reconstruction experts working in the field base their decision on personal experience or on foreign experience. These decisions are often not objective and interfere the investigation, especially in disputable cases. Often legal problems appear in the cases .

According to the literature sources [3], almost 47-52% of all the accidents cause collisions of cars. So it is possible to conclude that almost each seconda a car accident is a collision.

One of the most important parameters that should be determined during the carcrash investigation is the speed

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of a car before the accident. The calculation of the parameters in various situations differs. The experts performing the investigation work improve or create the investigation methodics in various cases.

The publication [4] presents the methods of speed determination in the case of car falling on a side and sliding when accidents take place in dangerous and sudden turnings.

The articles [4] and [5] also deal with the parameters of calculation in cases when a car collides with a pedestrian.

The methods of speed determination before accidents are presented in these cases: direct collision, when cars move one after another, direct sided collision and sided sliding collision as weel.

2. The Investigation of Collision of Two Cars

Each and every car accident is very individual, however, it is possible to distinquish several typical cases analising statistical data.

The most important parameters that should be determined at the period of car accident investigation are these:

1) the place of a car accident;

2) the speed of cars before the accident.

The place is often determined at the locality of the accident. Speed must be calculated. The article deals with the speed calculation methods before the crash in the cases of typical accidents.

3. The Determination of Car Speed before the Crash

3. 1. Calculation Parameters of Direct Collision

Presuming, that one of the cars before the crash did not move it is possible to conclude that obviously after a stroke both the cars moved together as one body.

Possible consigruenses:

1. Both cars are not braked and after the collision move freely (Fig 1.).

In this case the formula of kinetic energy is:

$$\frac{(m_1+m_2)v_1'^2}{2}=(m_1+m_2)g\psi_j=S_m, \quad (1)$$

here v_1' – primary speed after a stroke, m/s,

S_m – path of cars after a stroke, m,

ψ_m – coefficient of resistance to motion.

The coefficient is counted according to the formula:

$$\psi_m=\psi_r+\frac{P_a+P_t}{G\delta_m}, \quad (2)$$

ψ_r – road resistance coefficient;

$$\psi_r=\cos\alpha_r+\sin\alpha_r, \quad (3)$$

α_r – longitudinal road pitch; P_a – force of air resistance;

$$P_a=Wv_a. \quad (4)$$

Here W – stream line of a car Ns^2/m^2;

v_a – car speed *m/s*. P_t - force of transmision resistance. Determined according to the formula:

$$P_t=(2+0.009v_a)G_a\cdot 10^{-3}, \quad (5)$$

G_a – net weigth of a car , N; G – real weigth of a car, N; δ_m – coefficient of spinning masses;

$$\delta_m=1+\frac{(0.03+0.05i_b{}^2)G_a}{G}.$$

Here i_b – number of transmision evaluation of gear box;

Speed v_1' in formula (1) is counted up:

$$v_1=\sqrt{2g\psi_m S_m}. \quad (6)$$

Taking into account that one of the cars did not move before the stroke and that after it both the cars move together, it is possible to conclude that both the cars moved at the same speed after the stroke:

$$V_2=0; V'_1=V'_2.$$

The speed of a car before the stroke is:

$$V_1=\frac{(m_1+m_2)V'_1}{m_1}. \quad (7)$$

2. Both cars are braked and after the stroke moved separately along distance S_m (Fig 2) with primary speed v_1'. The speed after the stroke is determined using the the formula:

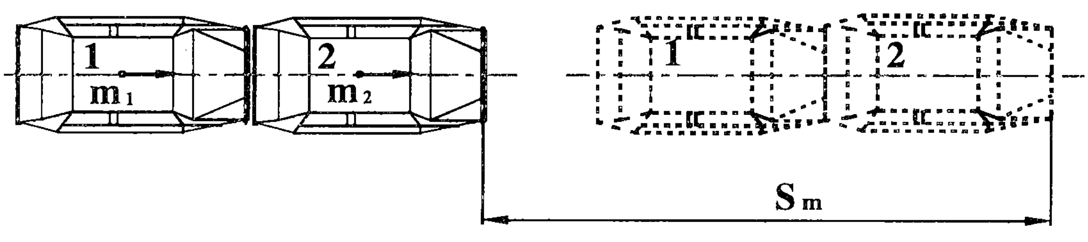

Fig 1. Scheme of direct collision when cars move without stopping

$$V'_1 = \sqrt{2g\varphi_x S_m}\,, \tag{8}$$

φ_x – coficient of tyre adhesion with a road,
φ_x values are presented in the table.

	Dry	Wet
asphalt or concrete road	0.7 - 0.8	0.35 - 0.45
ground (covered with gravel)	0.5 - 0.6	0.2 - 0.4
road coverd with slush (slippery road)	0.2 - 0.3	0.2 - 0.3
road covered with ice	0.1 - 0.2	0.1 - 0.2

The speed of the first car after stroke is calculated using the formula:

$$V_{a_1} = \sqrt{2g\varphi_x S_{s_1} + (V'_1)^2}\,. \tag{9}$$

The speed of the first car at the beginning of braking:

$$V_a = 0.5t_3 g\varphi_x + V_{a_1}\,, \tag{9 a}$$

t_3 – time of increasing slacken.

3. The unmoving car 2 is stopped, the first car – is not stopped. Aften the stroke both cars move together along distance S_m at the initial speed v_l' (Fig 3).

$$\frac{(m_1 + m_2)(V'_1)^2}{2} = (m_1\psi_m + m_2\varphi_x)gS_m\,. \tag{10}$$

In this case the kinetic energy will be:

V'_1 is found using the formula:

$$V'_1 = \sqrt{\frac{2g(m_1\varphi_x S_m + m_2\psi_m)S_m}{m_1 + m_2}}\,. \tag{11}$$

4. The unmoving car is not stopped. The first car is stopped before the collision and the distance of its braking S_{sl}. After the crash the first car moves along distance S_{ml}, and the second one – by S_{m2} (Fig 4).

In this case speed V'_1 will be:

$$V'_1 = \sqrt{\frac{2g(m_1\varphi_x S_{m_1} + m_2\psi_m S_{m_2})}{(m_1 + m_2)}}\,. \tag{12}$$

The main shortcoming of the method is that it does not work in the case of opposite or side sliding collision when both the cars move. The method serves as a base for speed calculations of cars after crashes only in such cases when the speed of one of the cars is already determined by questioning witnesses or drivers. The testimony of witnesses may be subjective. Road accident reconstruction experts using their objective investigation methods may get necessary objective data so the method in separate cases may be used.

3. 2. Calculation Parameters of Direct Side Collision

In the case of side collision cars usually turn around axis of their weight center (Fig 5). The weight centers position after crash turns by some angle.

Possible variants of side collisions:

Direct side collision

If the drivers of both cars stop, the scheme presents and fixes the braking distances S_{s1} and S_{s2}.

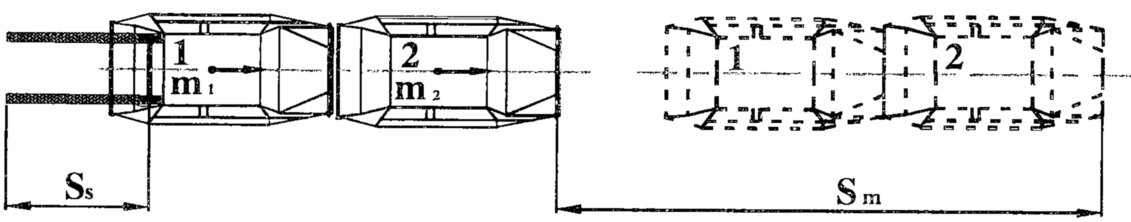

Fig 2. Scheme of direct collision when both cars are braked

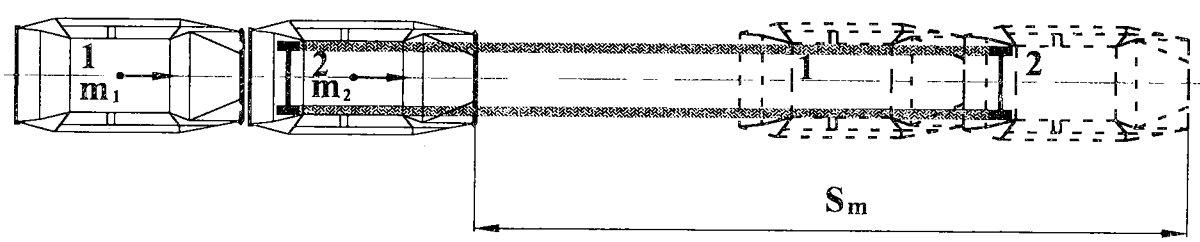

Fig 3. Scheme of direct collision when the car 2 is stopped

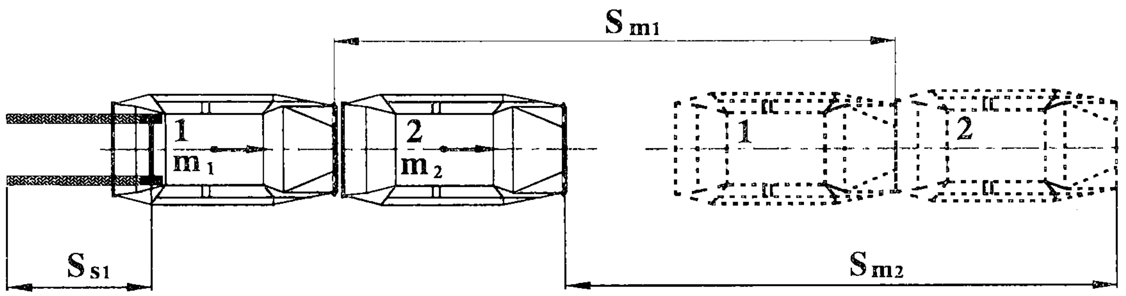

Fig 4. Scheme of direct collision when the car 1 before stroke is stopped

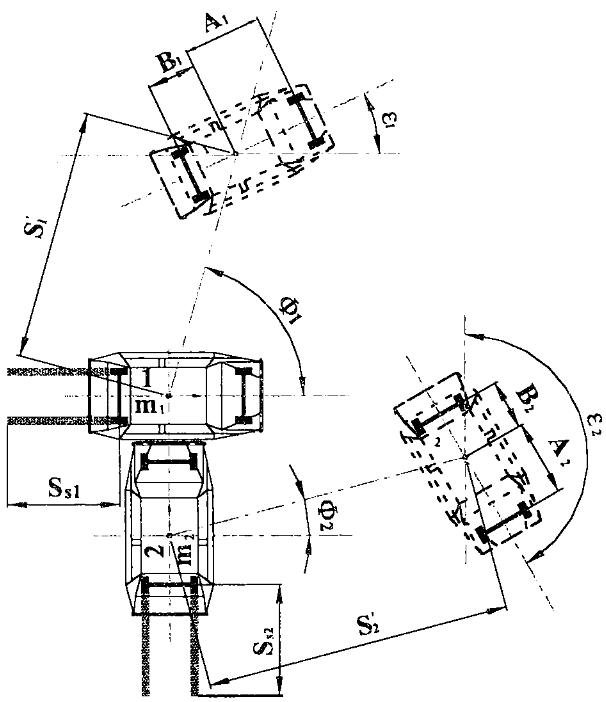

Fig 5. Scheme of direct side collision

After the accident the weight center of the first car moves by S_1, of the second – by S_2 turning angle ϕ_1 and ϕ_2.

The direction of the movement does not change, so it is possible to write the equation of movement amount:

$$m_1 V_1 = m_1 V'_1 \cos\phi_1 + m_2 V'_2 \cos\phi_2, \qquad (13)$$

$$m_2 V_2 = m_1 V'_1 \sin\phi_1 + m_2 V_2' \sin\phi_2. \qquad (14)$$

Here V_1' and V_2' – speed of cars after the crash.

Both V_1' and V_2' are determined taking into account that kinetic energy of each car is transformed into the work of car tyres rub. In this case cars move along distance S_{m1} and S_{m2} and turn around their weight centers by angles ε_1 and ε_2.

Work is performed when a car moves:

$$A' = m_1 g S_{m1} \varphi_x, \qquad (15)$$

m_1 – mass of car;

S_m – car movement after a crash;

φ_x – rub coeficient.

Work is performed when a car turns round:

$$A'' = R_{z_1} a_1 \varepsilon_1 \varphi_x + R_{z_2} b_1 \varepsilon_1 \varphi_x, \qquad (16)$$

a_1 and b_1 – distance from cars front and rear ends to the weight center;

R_{z1} and R_{z2} – normal reaction of a road affecting front and rear cars ends;

ε_1 – angle of first cars rotation, rad.

Reaction ise determined:

$$R_{z_1} \approx \frac{m_1 g b_1}{L'}; \; R_{z_2} \approx \frac{m_1 g a_1}{L'}, \qquad (17)$$

L' – basis of a car.

Total work formed during car accidend:

$$A' + A'' = \frac{m_1 g (S_{m_1} \varphi_1 + 2 a_1 b_1 \varepsilon_1 \varphi_2}{L'} = \frac{m_1 (V'_1)^2}{2}. \qquad (18)$$

The formula allows to calculate V_1':

$$V'_1 = \frac{\sqrt{2 g \varphi_x (S_{m_1} + 2 a_1 b_1 \varepsilon_1)}}{L'}. \qquad (19)$$

Analogically the speed of the second car V_2' is determined:

$$V'_1 = \frac{\sqrt{2 g \varphi_x (S_{m_2} + 2 a_2 b_2 \varepsilon_2)}}{L''}, \qquad (20)$$

L'' – basis of the second car;

ε_2 – angle of the second car rotation;

a_2 and b_2 – distance from car front and rear ends to the weight center of the second car.

These values (19) and (20) could be put into the equations (13) and (14) and work for calculation of the car speed before the crash:

$$V_1 = [\sqrt{2 g \varphi_x} (m_1 \cos\phi_1 \frac{\sqrt{S_{m_1} + 2 a_1 b_1 \varepsilon_1}}{L'} + m_2 \cos\phi_2 \times \times \frac{\sqrt{S_{m_2} + 2 a_2 b_2 \varepsilon_2}}{L''})] / m_1, \qquad (21)$$

$$V_2 = [\sqrt{2g\varphi_x}\,(m_1 \sin\phi_1 \frac{\sqrt{S_{m_1} + 2a_1 b_1 \varepsilon_1}}{L'} + m_2 \sin\phi_2 \times \frac{\sqrt{S_{m_2} + 2a_2 b_2 \varepsilon_2}}{L''})] / m_2 . \quad (22)$$

When V_1 and V_2 are known using (9) and (9 a) equations it is possible to determine the speed of cars before and at the beginning of braking. The determination of these parameters usually is the main task of road accident reconstruction experts.

3. 3. Sliding Side Collision

In case of sliding side collision the angle of a stroke α is not 90° degrees (Fig 6).

In these cases the same methodics (as in the case of direct side stroke) is used. The movement amount equation is being changed now:

$$m_1 v_1 + m_2 v_2 \cos\alpha = m_1 v'_1 \cos\phi_1 + m_2 v'_2\, \phi_2 , \quad (23)$$

$$m_1 v_1 \cos\alpha + m_2 v_2 = m_1 v'_1 \cos(\alpha - \phi_1) + m_2 v'_2 + m_2 v'_2 \cos(\alpha - \phi_2) \quad (24)$$

Speeds V_1' and V_2' after the crash are calculated according to equations (19) and (20).

Marking both right sides of (23) and (24) equations quantitys A_1 and A_2 it is possible to calculate the speeds before a stroke:

$$V_1 = \frac{A_1 - B_1 \cos\alpha}{m_1 \sin^2\alpha} , \quad (25)$$

$$V_2 = \frac{B_1 - A_1 \cos\alpha}{m_2 \sin^2\alpha} . \quad (26)$$

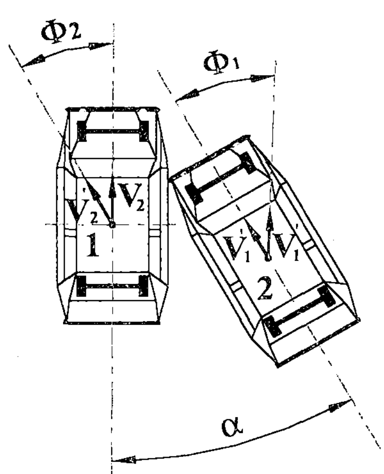

Fig 6. Scheme of sliding side collision

The speed rated by this method is not very precise because the losses of energy during car rotation are not evaluated. The speeds values are approximate.

The real speed of cars before the collision according to literature [6] is 10 –20 per cent higher than the rated one.

4. Conclusions

1. The method of speed determination before a crash in the case of direct collision is simple, however, the calculation is allowed only after making several presumptions. For this reason the real results slightly differ from the calculated ones.

2. Using the method for the determination of collision parameters in the cases of direct collision, practical results are available only when one car does not move. It is possible to determine the parameters in the cases of direct sided collision and sided sliding collision only when the speed of one car is known.

3. Distances S_{m_1} and S_{m_2} and also angles ϕ_1 and ϕ_2 presented in the equations (21) and (22) define the movement of car centers of gravity and their rotation. The parameters may differ a lot from the real braking trace in the place of a crash. For this reason it is very important to evaluate possible divergence in the process of the determination of the parameters.

4. The methods presented in the article for the evaluation of carscrash parameters are not absolutely accurate. However, despite all mentioned shortages they could be succesfuly used in special cases.

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